ARBOREAL LICHEN COVER AND ABUNDANCE IN FOUR AGES OF SELECTIVE CUT ENGELMANN SPRUCE — SUBALPINE FIR

(Moist Subzone)

PRELIMINARY STUDY

Province of British Columbia
Ministry of Forests

F.S. 189

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ARBOREAL LICHEN COVER AND ABUNDANCE IN FOUR AGES OF SELECTIVE CUT ENGELMANN SPRUCE - SUBALPINE FIR (Moist Subzone)

Preliminary Study

K.A. Palmer

July 5, 1982

Abstract

Standing crop of arboreal lichens in mature forest stands was compared to standing crop in 5, 10, 15 and 20 year old selectively cut stands in the Kamloops Forest Region, Clearwater District, B.C. Percent cover and abundance methods of assessment were used to compare lichen standing crop on a per tree basis. Results were inconclusive. Lichen percent cover and abundance data showed a skewed distribution, therefore log transformations were used in the analysis. Analysis of variance indicate differences in plotwise lichen cover and abundance exists but confounding factors made interpretation difficult. Average cover and abundance per tree was greatest in some 15 and 20 year old partially cut stands. In a stepwise linear regression the variables DBH, percent cover of coniferous foliage in the 2-4 m measurement interval and tree vigor accounted for a range of 23 to 39% of the variation in lichen cover and 9 to 51% of the variance in lichen abundance. A 4-way Analysis of Variance of selected variables indicates increasing age of site accounts for a significant difference in lichen abundance between trees if tree distribution, vigor and density are held constant. Stand density and tree distribution patterns appear to confound the age of partial cut, i.e. a densely grown 20 year old site may have equivalent average lichen abundance to a less dense 5 year old site. Retention of large *A. lasiocarpa* with substantial lichen abundance is recommended.

Management Recommendations Summary

a) Leave a number of heavily lichen covered midcanopy, medium vigor *Abies lasiocarpa*.

b) In addition to diameter limit logging, use of a faller selection program or marking system for the identification of good lichen seed trees is recommended.

c) Management of forest stands with markedly low overall lichen abundance are not likely to be enhanced by diameter limit logging alone.

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Acknowledgements

I would like to acknowledge the direction and assistance of Rick Ellis, Research Branch, Ministry of Forests, Victoria and Bruce Clark, Research Section, Kamloops Region, Ministry of Forests. I am particularly grateful to Sue Lofts for her field work, Mel Monteith and his staff, Clearwater District, Ministry of Forests and Don Baxter, Clearwater Timber Ltd. for their assistance. Susan Stevenson provided valuable advice and criticism throughout the duration of the project. Wendy Bergerud is gratefully acknowledged for her statistical advise.

1 INTRODUCTION

Arboreal lichens of the Engelmann Spruce - Subalpine Fir (ESSF) zone (Coupe, 1982) are the main source of mid to late winter forage for caribou within the drainages of the North Thompson River (Edwards et al. 1960). Clearcutting of stands within the ESSF zone completely removes the supply of lichen for a period of time. Preserving these stands from logging would cause a reduction in the annual allowable cut for the forest industry. It has been suggested that selective or partial cut logging might provide adequate lichen forage for caribou while maintaining sufficient timber supply. The impact of selective cutting on arboreal lichen cover and abundance is poorly documented for this area. Therefore, studies of lichen standing crop in selectively cut and mature forest stands are necessary.

In the subalpine, Bryoriad lichens that are used as forage by woodland caribou grow primarily on the branches of the main tree species Abies lasiocarpa and Picea engelmannii. A roughly defined lichen group consists of Alectoria sarmentosa a filamentous light green lichen and a complex of black, reddish or dark brown species of Bryoria, notably: B lanestris, B. fremontii, B. oregana, B. pseudofuscescens and B. vrangiana. The conditions for optimum growth and development of these plants are not well known. They are thought to be wind and cold tolerant (Ahti 1962) and to either require or be tolerant of high light intensity.

The subalpine environment is characterized by a short growing season, low temperatures, heavy snow cover and abrasive dessicating winds. Lichens survive in this environment due to their ability to endure long periods of unfavourable conditions in an inactive state. Most species can photosynthesize immediately when conditions become favourable. Scarcity of interspecific competitors allow lichens to coexist for long periods of time. There is no need to produce new biomass for to reproduce each year (Billings and Mooney 1968). Growth of this group is slow but is expected to vary with environmental conditions. Epiphytic species composition and abundance is known to respond to changes in light and moisture regimes (Culberson 1955, Hale 1955, Brodo 1961, Harris 1971).

Bryoriad tree lichens may have a preference for acidic bark (Barkman 1958, Brodo and Hawksworth 1977) and for certain ages and densities of forest stands (Laflamme-Levesque et al. 1980). Changes in mature forest stand densities as a result of windfall and disease can be expected to influence light and moisture regimes. Over time, this may affect lichen abundance. Selective or diameter limit logging can be viewed as a special type of forest "thinning". Retention of lichen cover on residual trees may be a function of cover present in the original mature forest as well as conditions in the residual stand.

Due to slow growth and response of lichens, studies on the impact of selective logging on lichen growth are not common. The effect of selective logging on the standing crop of lichens was investigated in the Selkirk Mountains by Stevenson (1979), but lichen growth over time was not studied. It was found that lowering the diameter limit would drastically reduce residual lichen abundance. A logging prescription of 50.8 cm diameter stump height was recommended as the optimum compromise between timber harvest and maintenance of lichen supply. Stevenson suggested that lichen growth rates may be affected following logging and that the relative impact of logging on lichen growth rates may be, in part, a function of the cutting prescription (i.e. diameter limit). Comparisons over time of lichen abundance in stands that have been logged to different diameters may reveal some aspects of the nature of lichen growth in response to disturbance.

Some quantitative studies of arboreal lichen have required the time consuming practice of stripping lichens from the trees and weighing them (Stevenson 1979, Rhoades 1980). Biomass estimates are then compared to biomass measurements and confidence limits are established. Other methods of lichen abundance assessment have been devised. Becker et al. (1977) used large wire grids for estimation and extrapolation. Esseen et al. (1981) measured the lengths of individual plants with an extended ruler. Stevenson (1979) used a standard clump of arboreal lichen to which total standing crop was compared. Estimates have been made from the ground (Stevenson 1979, Antifeau 1981, Rhoades 1981) and from within the tree (Pike et al. 1977). In

most cases considerable variation in the data occurred (Becker et al. 1977, Rhoades 1981, Esseen et al. 1981).

Trees with relatively high lichen abundance often occur in a clumped distribution (Nadkarni, pers. comm. 1981, Esseen et al. 1981). Islands of trees with abundant lichen may be dispersed in a matrix of relatively lichen-poor forest. The reason for this remains obscure although dispersal, light and moisture regimes and the availability of a hospitable colonizing substrate may be important. Selective cutting of these forest stands may introduce favourable light conditions. It may also reduce amounts of lichen necessary for further colonization. Certain methods of selective cutting may be more conducive to lichen regeneration than others. Therefore, a preliminary study of lichen percent cover and abundance was conducted in four chronological ages of partially cut ESSF forest stands, with the following objectives.

1.1 Objectives

The objectives of this study were to determine and compare cover and abundance of Bryoriad lichens on residual trees in four chronological ages of selectively cut stands. Logged stands were compared to mature forest stands adjacent to each cutblock. Every effort was made to use only those selectively cut stands that occurred within certain specified ranges in elevation, aspect, slope, physiography and timber type (Appendix 2A). Ideally, the only differences among lichen cover and abundance values in the selectively cut stand would therefore be due to the age of the selective cut and the amount present in the adjacent mature forest.

1.2 Scope

The scope of the study was to assess lichen cover on residual trees in diameter limit logged stands in the middle or montane subalpine Engelmann Spruce - Subalpine Fir moist subzone within the drainages of the North Thompson River. A chronological sequence of cuts were compared utilizing 5, 10, 15 and 20 year old selectively logged sites.

2 METHODS OF INVESTIGATION

2.1 Study area

The study area is located within the Clearwater district, 150 km north of Kamloops, B.C. (Figure 1) on the western slopes of the Shuswap Highlands within the Shuswap Metamorphic complex. These highlands consist of gentle or moderate sloping plateaus from 5,000 to over 7,000 feet. They are drained by the Clearwater, North Thompson, Adams and Shuswap Rivers. The effects of glaciation in the region were to reduce the upland relief and steepen the valley sides (Holland 1976). The oldest rocks are in the metamorphic series, and are provisionally assigned to the Precambrian (Walker 1931). The bedrock lies under thick till. Soils range from Orthic Humo-Ferric Podzols to weak Orthic Ferro-Humic Podzols (Lloyd 1979). The area is covered by mature and disturbed montane and subalpine Engelmann Spruce - Subalpine Fir. These forests have a mosaic and repetitive fire history (Hamet-Ahti 1965). The mean annual precipitation is 15.5 cm with 77 percent as snow (Canada Department of Transport 1968). Estimates of mean annual precipitation (15.5 cm) are conservative and based on the nearest weather station in Vavenby, B.C. Average snow depths in the study area are expected to be greater than those given for Vavenby. Frequent low pressure fronts moved by northwest winds are typical weather patterns for the area.

2.2 Control and Sample Plot Selection

Six hundred trees were sampled in selectively cut sites. Four hundred trees were sampled in mature forest (control) sites. Twelve selectively cut ESSF forests and eight mature forests adjacent to the selectively cut sites were sampled. Selectively cut sites were chosen on the basis of age of cut and similarity of physiography (Appendix 2A). A total of four ages of site were chosen in the following sequence; 5 years since cut, 10 years, 15 years and 20-25 years since cut. Some plots of different ages occur within one physiographic location. For example, Candle Creek has a 10 year old and a 20 year old selectively cut plot and one adjacent mature forest plot.

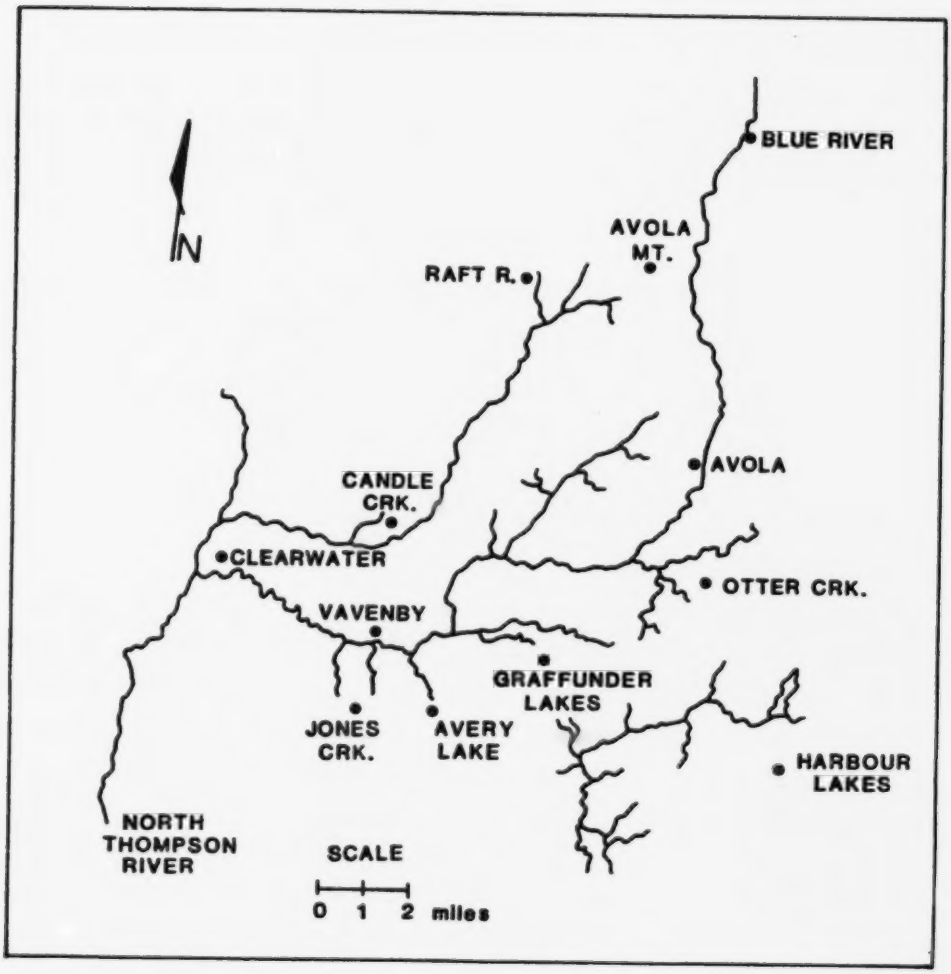


Figure 1. Study area and plot locations.

Plots were located on transects running from the edge of the cutblock or mature forest on a random compass bearing. Each plot was composed of a number of fixed radius subplots (11.34 m) at regular intervals of 50 m along the transect. Subplots were laid out and trees were sampled in each subplot until 50 trees for the plot were obtained. Thus, the number of subplots was a function of tree density on the site. Where the final subplot contained more than the number of trees to make 50 for the plot, the additional trees were recorded for DBH and species alone. A total of fifty-two 11.34 m radius subplots were completed.

2.3 Criteria for Site Selection

Criteria for plot selection are described in Appendix 2B. A description of the plots is included.

2.4 Sampling Design and Information Collected

2.4.1 Lichen Sample Design

Each tree was visually divided into three 2 m high belts from the ground to 6 m above the ground (Figure 2). The width of each belt was defined by the furthest reaching branch. A two meter stick was used to estimate heights and widths. Within each belt an estimate of lichen cover repetition and live foliage were recorded and expressed as the sum of the lichen cover repetition and abundance for each sampling interval.

a) Cover Repetition of Live Coniferous Foliage

Percent cover of live coniferous foliage occupying each 2 meter belt was estimated. Views were taken from a downslope location or when this was not possible from a maximum vantage point. The content of the belt was visualized as two dimensional. Percent cover of live foliage was estimated from a total of branches, lichens, and dead material. The live foliage was considered a percentage of the total material present in the belt. Boles of trees were not included.

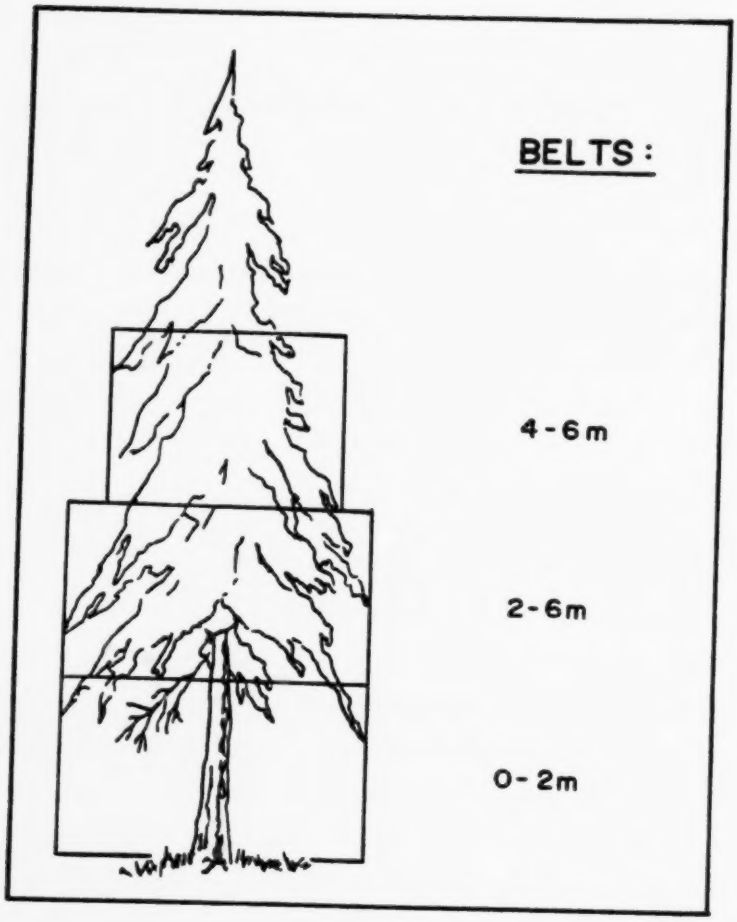


Figure 2. Lichen estimate belts for study trees.

b) Cover Repetition of Arboreal Lichens

Horizontal percent cover of arboreal lichens on branches was estimated for each belt. Again, the belt was visualized as two dimensional. Percent cover estimates were estimates of the lichen cover on all easily visible branches within the belt. A median number was selected between the heaviest covered and the most sparsely covered branches.

c) Lichen Abundance: the Clump Method (Stevenson 1979)

In addition to cover ratings for each plot, a lichen abundance assessment was done for 14 of the 20 plots. A standard lichen clump of an average size was selected from the first plot. This clump was mounted on a card and carried in the field. The standard clump was used to estimate the number of corresponding clumps present in each tree. Only lichen clump estimates from the 2 - 4 m belt were analysed in order to avoid the effect of snow on lower branches and to ensure good visibility.

2.4.2 Tree Variables

A series of estimates and measurements were completed for each tree that was assessed for lichen cover and abundance. DBH and height were measured. Tree species were recorded and estimates were made of tree growth release, crown width, vigor, % live crown and tree distribution with respect to nearest neighbour. Tree growth release was estimated by counting the number of years of relatively rapid leader growth. Tree vigor was estimated using a scale of 1 to 5. The scale described proportions of dead or dying branches to live branches, presence or absence of live foliage, bark intactness and evidence of injury or disease. Percent live crown was also estimated using an estimate of the percentage of the crown composed of dead or dying material. Tree distribution was estimated by recording the number of sides of the tree crown enclosed by neighbouring trees. An average of seven trees were cored in each plot. Trees that were representative of each level in the canopy were cored. Width of release and suppressed rings were recorded.

2.5 Site, Soils and Vegetation Description

Standard forest ecological description techniques (Walmsley et al. 1980) were used to describe the site and vegetation. A vascular plant species list was compiled for the subplot that best characterised the cutblock or mature forest plot vegetation (Appendix 1A). Common lichen, moss and liverwort species are listed in Appendix 1B.

3 DATA ANALYSIS

The raw data were prepared for analysis by compiling average percent arboreal lichen cover per tree per plot. Average number of standard lichen clumps per tree was calculated as:

$$\text{clumps per meter of crown width} = \frac{\#\ \text{clumps/tree crown width (m)}}{\#\ \text{trees}}$$

The skewed distribution of the data and outlying data points are illustrated in histograms (Appendix 3A and 3B). Log transformations were used to normalize the data. An F-max test (Sokal and Rohlf 1981) was used to test for heterogeneity of the transformed data (Appendix 3C). An overall analysis of variance (Model I ANOVA, Sokal and Rholf 1981) was used to test for a significant difference in average lichen cover and abundance for all plots. Duncan's multiple range tests were used to illustrate mean lichen cover and abundance per plot and indicate overlap between plot means.

A Kruskal-Wallis non-parametric analysis of variance by ranks (Sokal and Rohlf 1981) was used on non-transformed data to test for inter-age differences in lichen cover and abundance between plots. Differences in selective cut lichen abundance and cover according to age of site, or time elapsed since the selective cut, were tested by analysis of variance and orthogonal contrasts. A stratification after sampling (Appendix 3D) was used to construct a 4-way design Analysis of Variance . All parametric statistics were for interpretation of trends in lichen cover and abundance.

Stepwise linear regression of the independent variables listed in Appendix 3D was completed on log transformed data. Independent variables in each age of selective cut and mature forest control plots were regressed against the dependant variables: lichen percent cover in the 2-4 m measurement belt and lichen clump abundance estimates for each tree. Lichen abundance and cover was plotted against DBH.

4 RESULTS

The results of this study can be used to interpret lichen cover and abundance on a per tree basis only. Interpretation of lichen cover and abundance on a per area basis is not possible from these data. The data presented here are based on estimates of lichen standing crop and are not representative of biomass of lichen available to caribou because they do not take into account the very great differences in number of trees per unit area between unlogged and selectively logged stands. Due to the high relative proportion of poorly covered or low abundance lichen trees, the data distribution is skewed to the right with sporadic outlying data points. Therefore parametric statistics are used here only for the elaboration of general trends in lichen cover and abundance according to age class and environmental differences between plots. Transformations have been used to normalize the data and allow for the use of F probabilities in linear regressions.

There is an important distinction between lichen cover and abundance. Lichen cover refers to average percent cover of arboreal lichen on the branch substrate within the measurement belt. Lichen abundance estimates refer to the numbers of lichen clumps in the belt in comparison to a hand held standard--1.5 g clump of *Alectoria sarmentosa*, *Bryoria oregana*, *Bryoria glabra*, etc. One is an estimate of lichen-substrate cover per tree. The other is an estimate of the number of standard clumps of lichen per tree width. This distinction becomes important in evaluating the environmental conditions that are conducive to lichen growth. High cover values are not necessarily equivalent to abundant lichen. High cover values may indicate

that a healthy crop of lichen is developing and may become abundant if conditions remain optimal, providing the life expectancy of the substrate branch is an average life expectancy.

Analysis of variance and plotwise comparisons of log transformed lichen data (Tables 1 and 2) indicate a significant between-plot variance in lichen abundance and cover. There is considerable tail overlap between non significantly different groups. The Candle Creek twenty year old cutover site has low lichen cover that is characteristic of some five and ten year old sites. Mature forest cover mean values are slightly higher than adjacent selective cuts with the exception of the Graffunder Lake 20 year old sites and the Harbour Lake sites. All the Graffunder Lake cutover sites and the Jones Creek mature forest appear to have distinctly different lichen cover than any other plot or group of plots. A non-parametric analoque to ANOVA was used to determine if a significant difference in plotwise lichen abundance medians existed. Kruskal-Wallis ANOVA (Sokal and Rohlf 1981) results indicated a significant difference. $P(X^2 \geqslant 15.06) \leqslant .001$ in ranked lichen abundance between plots did occur.

Due to high between plot variance, the age of the selective cut does not account for a significant difference in lichen cover or abundance (Table 1). The plot variability was high even within each age class ($F = 7.23$ for lichen cover and $F = 3.68$ for lichen abundance - see Table 3). This is partly due to many confounding factors, such as different cut methods, which could not be controlled in the sampling. There is no indication of differences due to the age of the cutblock (not even between mature and all other ages - Table 3), although such differences may be obscured by the high variability between plots.

Table 1. Analysis of Variance and Duncan's Multiple Range Test of mean lichen abundance per plot (log transformed)

DEPENDANT VARIABLE = LICHEN ABUNDANCE (MEAN CLUMP/TREE)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	13	31.61028712	2.43156055	4.14
ERROR	682	400.69386985	0.58752767	
CORRECTED TOTAL	695	432.30415697		

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE
LICHEN ABUNDANCE

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT

ALPHA LEVEL = 0.5 DF = 682 MS = 0.587528 M = MATURE FOREST

GROUPING			MEAN	N	PLOT	AGE
	A		0.595967	48	GRAFFUNDER	20
	A		0.524249	50	GRAFFUNDER	20
B	A		0.373182	50	GRAFFUNDER	15
B	A		0.370552	50	OTTER	M
B	C		0.162011	50	AVOLA	M
B	C	D	0.147749	49	RAFT	M
B	C	D	0.133144	50	AVERY	10
B	C	D	0.132777	50	RAFT	5
B	C	D	0.117911	50	OTTER	15
B	C	D	0.110547	49	GRAFFUNDER	M
B	C	D	0.043925	50	AVERY	M
B	C	D	0.033284	50	CANDLE	20
	C	D	-0.087674	50	CANDLE	M
		D	-0.205234	50	AVOLA	5

Table 2. Analysis of Variance and Duncan's Multiple Range Test of mean lichen cover per plot (log transformed)

DEPENDANT VARIABLE = LICHEN COVER 2-4 M

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE
MODEL	19	40.42482481	2.12762236	7.71
ERROR	948	261.66929727	0.27602247	
CORRECTED TOTAL	967	302.09412208		

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE
LICHEN COVER 2-4 m

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT

ALPHA LEVEL = 0.5 DF = 948 MS = 0.276022 M = MATURE FOREST

GROUPING			MEAN	N	PLOT	AGE
	A		1.275689	48	GRAFFUNDER	15
	A		1.152093	47	GRAFFUNDER	20
B	A		1.052699	48	JONES	M
B	C		0.922333	46	GRAFFUNDER	20
D	C		0.802333	50	OTTER	M
D	C	E	0.753649	47	HARBOUR	15
D	C	E	0.752220	50	CANDLE	10
D	C	E	0.743441	48	GRAFFUNDER	M
D	C	E	0.715849	43	RAFT	5
D	C	E	0.713763	50	JONES	10
D	C	E	0.703989	49	HARBOUR	5
D	C	E	0.679920	48	AVERY	M
D	C	E	0.679711	49	CANDLE	M
D	C	E	0.677343	47	RAFT	M
D	C	E	0.668034	50	OTTER	15
D		E	0.627407	50	AVERY	10
D		E	0.627050	50	CANDLE	20
D	F	E	0.576296	49	AVOLA	M
	F	E	0.527415	50	HARBOUR	M
	F		0.373686	49	AVOLA	5

Table 3. Analysis of Variance of mean lichen abundance and mean lichen cover per age class

DEPENDENT VARIABLE: LICHEN COVER 2-4 m

SOURCE:	df	SS	F	Prob. F	
AGE	4	10.59	1.33	0.3051	N. Sig.
PLOT (AGE)	15	29.92	7.23		
ERROR	948	261.67			

DEPENDENT VARIABLE: LICHEN ABUNDANCE 2-4 m

SOURCE:	df	SS	F	Prob. F	
AGE	4	12.29	1.42	0.3031	N. Sig.
PLOT (AGE)	9	19.48	3.68		
ERROR	682	400.69			

A 4-way crossed design ANOVA model for lichen cover and abundance (Table 4), was constructed using tree vigor and distribution variables. In this model, the age of the selective cut accounts for a significant difference in lichen abundance when the variables subplot tree density, tree distribution with respect to nearest neighbour and vigor are all held constant. Relationships between these variables and lichen abundance are illustrated in Figure 3. These results indicate a higher lichen abundance in open stand densities of less than 20 trees per 11.34 m radius subplot. Note that the Coefficient of Variation is high for this 4-way model.

Stepwise linear regression of all tree variables accounting for variation in lichen cover and abundance are shown in Tables 5 and 6. For convenience regressions were performed on similar ages of selective cuts. DBH and percent cover of coniferous foliage in the 2-4 m belt account for a range of 23 to 33 percent of the variation in lichen cover (Table 5). These two variables account from 9 to 39 percent of the variation in lichen abundance (Table 6). R^2 values are generally low but are significant at the .05 alpha level for entry into the model. DBH and percent cover of live coniferous foliage have a relatively low order of entry into the model. They account for comparatively high variance in lichen cover and abundance, although coniferous foliage has a similar frequency of entry into the model as other crown characteristics such as width and vigor. Lichen cover and abundance tend to be unpredictable after a DBH of 26 cm (Figure 4). Significant variables with a low frequency are tree distribution and release estimates. Tree height is a relatively important variable at the low frequency at which it enters the model.

Table 4. 4-Way cross Analysis of Variance: lichen abundance vs. variables; tree vigor and distribution, stand density and age of partial cut

Source	df	Type 1 SS	F Value	P F
Vigor	1	7.0060	0.09	0.7586
Distribution	2	3052.9783*	20.60*	0.0001*
Vig * Dist	2	291.3221	1.97	0.1414
Density	1	490.8647	6.62	0.0104
Vig * Den	1	413.4823	5.58	0.0186
Dist * Den	2	213.5096	1.44	0.2380
Vig * Dist * Den	2	36.2951	0.24	0.7829
Age	4	1672.4843	5.64	0.0002
Vig * Age	4	316.3398	1.07	0.3723
Dist * Age	8	1415.1351	2.39	0.0159
Vig * Dist * Age	8	697.1188	1.18	0.3121
Den * Age	4	279.3815	0.94	0.4392
Vig * Den * Age	4	222.5537	0.75	0.5579
Dist * Den * Age	8	650.5453	1.10	0.3639
Vig * Dist * Den * Age	12	630.3662	1.70	0.1319

DEPENDENT VARIABLE: CLUMP

Source	df	Sum of Squares	Mean Square	F Value
Model	56	10389.3829	185.5247	2.50
Error	432	32017.6633	74.1150	
Corrected Total	488	42407.0461		

P (F .0001) STD DEV = 8.609 CV = 140.228 Clump Mean = 6.1393

*Note: Underlined values are significant.

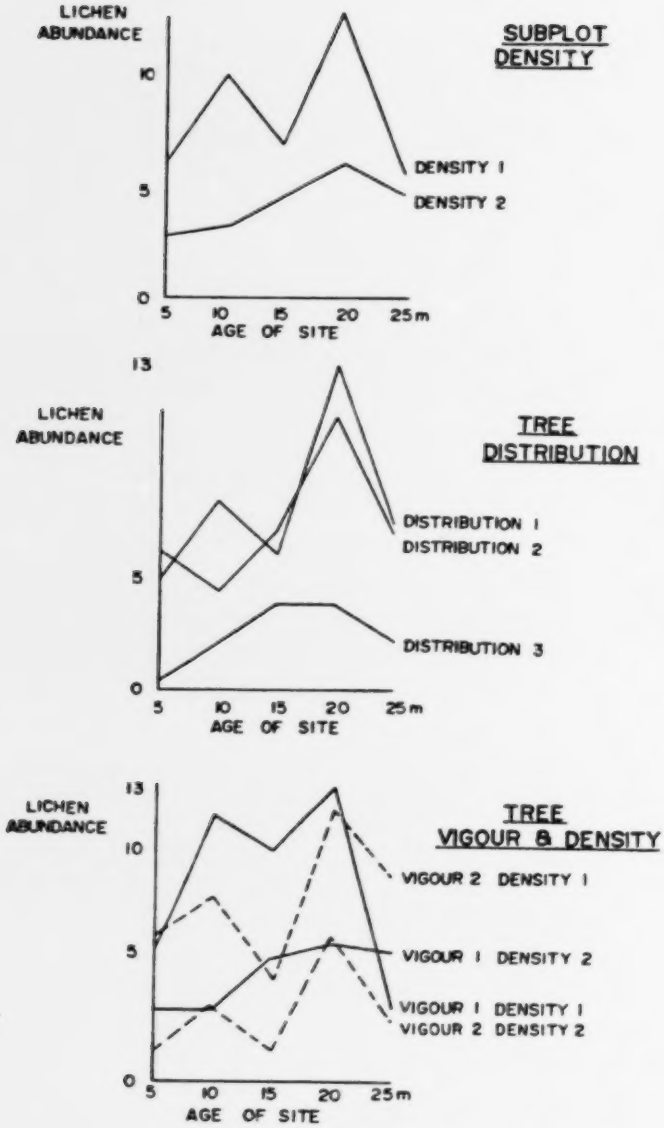


Figure 3. Plotted means of lichen abundance per subplot as a function of density, tree vigor and distribution for each age of partial cut.

Density 1: 20 trees per subplot; Density 2: 20 trees per subplot; Distribution 1: open crown and closed on one side; Distribution 2: closed on 2 sides and 3 sides of crown; Distribution 3: closed on all sides of crown, clumped and super clumped;
Vigor 1: poor to medium; Vigor 2: good to super.

Table 5. Stepwise linear regression of all independent variables accounting for variance in lichen cover by age of selective cut

AGE OF SITE:	VARIABLE ENTERED:	R^2	F	PROB F
5	DBH	.23	10.32	.0017
	% LIVE CROWN	.29	9.64	.0023
	CROWN WIDTH	.33	7.40	.0017
	BIOMASS ESTIMATE 2-4 m	.35	3.88	.0511

THE VARIABLES TREE SPECIES, TREE VIGOR, TREE HEIGHT, RELEASE, DISTRIBUTION, CONIFEROUS FOLIAGE OR BIOMASS ESTIMATE DID NOT MEET THE .05 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL. n=141

10	TREE HEIGHT	.16	9.98	.0019
	CROWN WIDTH	.22	9.33	.0027
	TREE VIGOUR	.24	5.89	.0165

THE VARIABLES DBH, % LIVE CROWN, TREE RELEASE, TREE SPECIES, TREE DISTRIBUTION, CONIFEROUS FOLIAGE OR BIOMASS ESTIMATES DID NOT MEET THE 0.05 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL. n= 150

15	CONIFEROUS FOLIAGE	.26	15.30	.0001
	RELEASE	.30	5.70	.0175
	% LIVE CROWN	.32	5.56	.0198

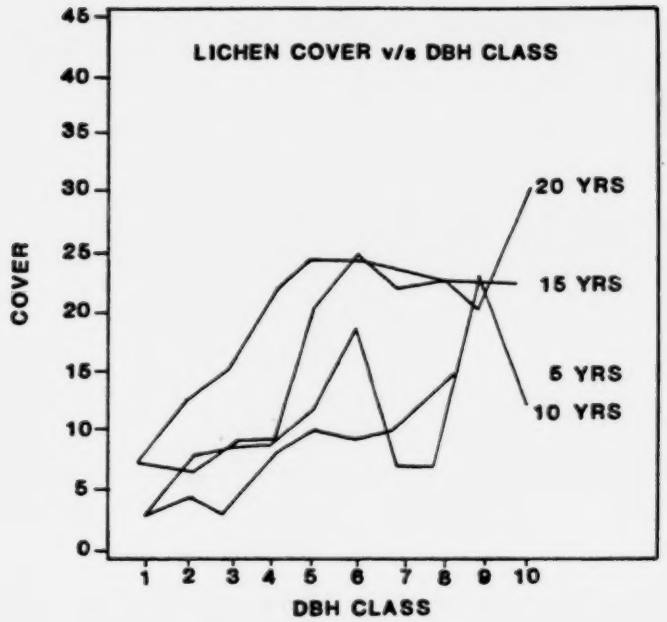
THE VARIABLES DBH, HEIGHT, VIGOR, TREE SPECIES, CROWN WIDTH, TREE DISTRIBUTION OR BIOMASS ESTIMATE DID NOT MEET THE 0.05 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL. n=145

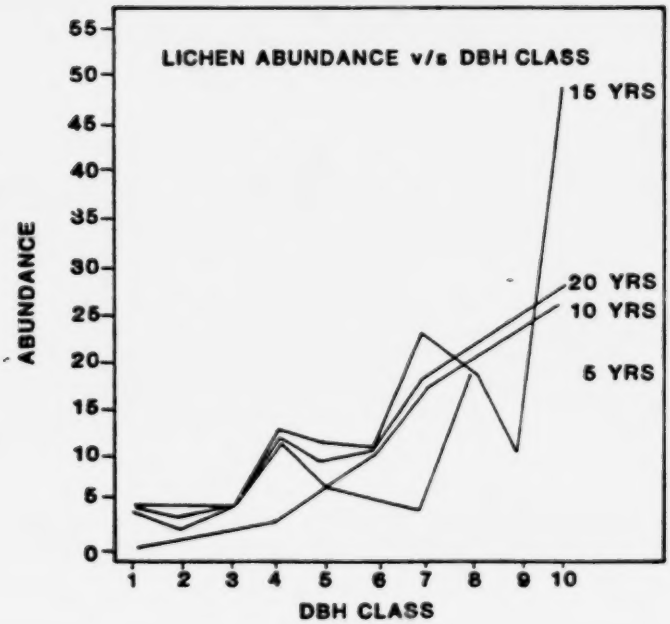
20	DBH	.33	6.93	.0095
	TREE VIGOR	.39	13.77	.0003
	BIOMASS ESTIMATE	.44	7.06	.0089
	TREE DISTRIBUTION	.45	6.23	0.0138
	TREE SPECIES	.47	4.36	0.0387

THE VARIABLES TREE HEIGHT, % LIVE CROWN, TREE RELEASE OR CONIFEROUS FOLIAGE DID NOT MEET THE 0.05 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL. n=143

Table 6. Stepwise linear regression of all independent variables accounting for variance in lichen abundance by age of selective cut

AGE OF SITE:	VARIABLE ENTERED:	R^2	F	PROB F
5	DBH	.39	41.10	.0001
	CONIFEROUS FOLIAGE	.51	4.98	.0283
	TREE HEIGHT	.55	5.09	.0268
	TREE SPECIES	.57	3.66	.0590
	THE VARIABLES, TREE VIGOR, % LIVE CROWN, CROWN WIDTH, RELEASE, DISTRIBUTION OR BIOMASS ESTIMATE DID NOT MEET THE 0.05 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL. n=100			
10	DBH	.30	10.14	.0027
	% LIVE CROWN	.38	4.60	.0376
	THE VARIABLES TREE SPECIES, HEIGHT, DISTRIBUTION, VIGOR, RELEASE, BIOMASS ESTIMATE OR CONIFEROUS FOLIAGE DID NOT MEET THE 0.05 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL. n=50			
15	CONIFEROUS FOLIAGE	.09	7.34	.0080
	BIOMASS ESTIMATE	.12	5.84	.0177
	CROWN WIDTH	.14	6.27	.0141
	THE VARIABLES TREE SPECIES, DBH, HEIGHT, DISTRIBUTION, RELEASE, VIGOR OR % LIVE CROWN DID NOT MEET THE .05 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL. n=100			
20	DBH	.25	15.05	.0002
	TREE VIGOR	.31	3.29	.0003
	TREE DISTRIBUTION	.33	7.20	.0082
	TREE SPECIES	.36	4.49	.0360
	THE VARIABLES TREE HEIGHT, RELEASE, % LIVE CROWN, CROWN WIDTH, BIOMASS ESTIMATE OR CONIFEROUS FOLIAGE DID NOT MEET THE 0.05 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL. n=148			





DBH CLASSES: 1 = 8-10 cm; 2 = 12-15 cm;
3 = 16-19 cm; 4 = 20-23 cm; 5 = 24-27 cm;
6 = 28-31 cm; 7 = 32-35 cm; 8 = 36-39 cm;
9 = 40-43 cm; 10 = 44-47 cm.

Figure 4. Lichen cover/lichen abundance versus dbh classes.

5 DISCUSSION

Plotwise average lichen cover and abundance values are a function of both environmental conditions in the cutblock and the time elapsed since logging. The variables that are important to lichen cover and abundance in this study are tree size, substrate conditions, and stand configuration.

No single variable accounts for major changes in lichen cover or abundance. For instance, although time elapsed since selective cutting may be significant in terms of both cover and abundance, high stand density and rapid stand growth may cause a delay in lichen growth over time. Abundance of lichen in the plot prior to logging is probably also important. However, the lichen abundance in mature forest sites adjacent to some selective cuts may not represent the original lichen abundance in the selective cuts. Some selective cuts are often logged with little residual mature forest remaining.

Average lichen cover and abundance per plot is an expression of the overall lichen on the site and is a function of environmental conditions in the plot. This study estimates standing crop of arboreal lichen and as such is only an indication of trends in growth response over time. It serves as a preliminary investigation of lichen standing crop as affected by selective cut logging and is an analysis of lichen cover and abundance on a per tree basis only.

5.1 Lichen Cover and Abundance: Planned Comparisons of age of Selective Cuts

Log transformed average lichen cover and abundance values were determined for all the sites. Most sites are very similar with some notable exceptions. The Graffunder Lake 20 year old selectively cut sites and the Jones Creek mature forest have significantly higher lichen cover than any other site, although high variance makes overlap between this group of plots common. The Graffunder Lake forests were cut to intermediate utilization standards selecting for large spruce. Many large Subalpine fir were left. The Jones Creek mature forest had a high density of dead trees, all relatively intact and with fairly high lichen cover. Similar trends in lichen abundance occur for Graffunder Lake selective cuts. The Avola Mountain mature forest, 5 year

old site, and the Candle Creek 20 year old site have significantly lower lichen cover and abundance than any other site.

In general, mature forests show no clear trend toward higher lichen cover or abundance than the adjacent selectively cut sites. For instance, Candle Creek mature forest mean lichen cover values fall between the 10 year old and 20 year old site values. Cover values in the Candle Creek 10 year old site are generally high due to the presence of substantial cover of fine, hairlike Bryoria lanestris. This site was thinned before it could be assessed for lichen abundance. General field impressions were that average lichen abundance on this site would be fairly low due to lack of development of large clumps of heavier Bryoriad species and would represent an inaccurate representation of potential lichen crop. Also, the 20 year old site at this same location did not support as much lichen cover in comparison to the 10 year old site or the adjacent mature forest. This 20 year old site was very densely overgrown. Generally, lichen cover and abundance was highest where trees faced into clearings.

A number of confounding factors have probably resulted in high between plot variance in this and other cases. Within-plot variance is homogeneous as indicated by F-max tests, however, individual plots are so different from each other as to make within age of cutblock plot variance high. For this reason no significant difference between age of site occurs in the overall analysis of variance and in the planned comparison of lichen abundance in the ages of selective cuts. Between-plot variance is marked enough for further orthogonal contrasts to be non-significant. It would appear that the significance of age of selective cut is obscured by other factors, particularily when the range in age is less than 30 years. Five year intervals between selective cuts may not be long enough to show a significant difference in between age variance in lichen abundance or cover. Growth increment of lichen is remarkably slow but is expected to vary with environmental conditions.

The 4-way analysis of variance model indicates age of selective cut is significant when the variables vigor, subplot tree density and degree of crown closure of neighbouring trees are held constant. These variables were

subjectively chosen. The model has a number of limitations and can only serve as an exploratory tool. It suggests that given similar environmental conditions with respect to tree distribution, density and vigor, a given tree in an older selective cut site will tend to have higher lichen abundance than a tree in a recent selective cut site. The model further illustrates that underlying, unmeasured variables probably have a marked influence on lichen abundance, most notably light availability as crudely exemplified by the significance of subplot tree density and distribution variables. Initially, selective cut logging may open montane Engelmann Spruce - Subalpine Fir stands. However, a clumped tree distribution may occur as growth release of residual trees advances. This was the case in the very dense Candle Creek 20 year old site (see above). The disturbance caused by logging and its effect on the patchy distribution of lichen abundance (Esseen et al. 1981) is further complicated by site productivity and the resultant stand configuration.

Complex interactions between vigor and tree distribution also suggest underlying confounding factors. For instance, the model indicates that trees with low vigor ratings tend to have significantly greater lichen abundance when growing in an open distribution, but only in selective cut stands. Mature forests stands did not show this relationship. Mature forest stands generally have lower light intensities than selectively cut sites. Poor vigor trees in selective cut sites have probably been in poor condition for a shorter period of time than those in mature forests as most snags are removed during logging (Montieth, pers. comm.). Although snags occasionally support abundant lichen (Ahti 1962) they may not be a long standing source of lichen. It remains to be determined for what period of time a tree with low vigor supports substantial lichen abundance. It is probable that stand density and vigor alone are insufficient information for explaining abundance of lichen. Other variables may be of greater importance. The significance of vigor-distribution relationships in mature and selectively cut stands may be due to a combination of low light and low nutrient availability in declining trees. It is also likely that the model does not distinguish between vigor classes on a level that is important to lichen standing crop. However, it

appears that stand configuration interacts with tree vigor in some way. It is possible that the open growing poor to medium vigor trees on 5-15 year old selective cut sites were contributing significantly to average lichen abundance per subplot. Most of the vigorous trees remaining on selectively cut sites are small and rapidly growing. These trees do not have high lichen abundance in comparison to the larger, less vigorous trees in the selective cut sites. The interaction between tree vigor and lichen abundance has been a subject of interest (Ahti 1962, Stevenson 1979). It has not been determined whether declining trees actually possess significantly more abundant lichen than vigorously growing trees. Nor has it been determined whether trees with low vigor and high lichen abundance make up a significant proportion of total forest stands. Lichen abundance and tree vigor relationships appear to be further complicated by light availability. A study designed specifically to investigate tree vigor and lichen abundance relationships is recommended.

5.2 Regressed Variables and Confounding Factors

Stepwise linear regressions of the independant variables shown in Table 4 and Table 5 and summarized in Table 6 have low but significant total R^2 values. Tree DBH, and percent cover of coniferous foliage within the measurement belt consistently maintain first or second order of entry into the models where they occur. Plots are grouped together by age of selective cut for clarity.

The importance of coniferous foliage and DBH to lichen cover and abundance is probably a function of light and moisture availability and time for lichen growth and development. An increase in DBH appears to be correlated with an increase in lichen cover or abundance but this relationship appears to lose its predictability for trees above the 28-35 cm size class. Perhaps the overall light conditions, stand density, rapidity of tree growth and the presence of branches in the sample belt are unmeasured variables that affect substrate availability and therefore affect lichen standing crop. The absence of lower branches on some large trees (28-35 cm DBH) makes predictions of lichen abundance and cover difficult when based on DBH alone. Retention of

lower branches by the tree may be related to light availability. During growth of the tree, older branches occupy progressively inferior positions in the crown. Light availability influences suppression of growth in these inferior branches (Forward and Nolan 1961a). The degree of lower branch suppression is dependent on whether trees are open grown or enclosed. This in turn depends on stand development and site productivity. The same light conditions required for lower branch retention are probably also required for development of an abundant lichen crop. It follows that light that is available to branches is also available to lichen, therefore branch development may parallel the history of lichen abundance on a particular branch. Correlations between light conditions and Bryoriad productivity should be drawn from data collected specifically to explain this relationship, however.

Accurate light measurements are limited in time and space. One light measurement per site will be strongly influenced by weather, position of measurement, time of day and other problems (Anderson 1964). Percent cover of live coniferous foliage used in the linear regressions is a surrogate for such a variable and is relatively important for explaining variance in lichen abundance and cover. Percent cover of live coniferous foliage is correlated with both lichen abundance and cover. Presumably light availability is restricted by the presence of foliage. Foliar development, especially leaf size and position, has been used to measure light indirectly (Horn 1965). Bark characteristics such as pH and moisture potential are also influenced by foliar compositions (Plitt and Pessen 1924, Barkman 1958, Scorepa et al. 1979).

Selective cutting of Engelmann Spruce - Subalpine Fir stands will undoubtably increase light availability to residual trees and to residual lichens. The effect of this additional light may be offset, however, by rapid growth and foliar development of young, poorly colonized trees. Brix (1981) found stand thinning increased needle mass per tree, but did not increase crown width above the 12th whorl in the crown. In studies of branch growth in Pinus resinosa, Forward and Nolan (1961b) determined that an increase in apical growth occurred only in those axis whose local environment had

changed. For lichen crop development stand thinning or selective cut logging should strike a balance between maximum tree release, improved light conditions and minimum foliar development of lower branches. These conditions may represent hospitable lichen substrate, but they may be sufficient only if lichen is relatively abundant in the stand prior to the selective cut. Tree release does not appear to be a critical variable for explaining variation in lichen cover or abundance. This is perhaps because the estimation of tree release is made subjectively and is not an adequate description of tree release. Other factors may be more important to lichen growth.

Periderm development is influenced by time of exposure to light (de Zeeuw 1947). The degree of bark roughness has long been known to influence epiphytye community development (Raup 1930, Barkman 1958, Hoffman and Kazmierski 1969, Harris 1971, Yarranton 1972). Intraspecific variation in bark development may also affect Bryoria spp. standing crop but data was not collected specifically to explain lichen productivity with respect to bark variability.

Tree species is believed to be an important variable (Ahti 1962). Most spruce have been logged from these sites and an incomplete picture of substrate preference of Bryoriad lichen for Engelmann spruce or subalpine fir, if it exists at all, remains.

5.3 Management Recommendations

Selective cut logging does not completely remove lichen from a site, but it may diminish cover and abundance levels to a low level depending on the original lichen crop. Original lichen cover and abundance was not known in this study. The impact of selective, diameter limit, salvage and intermediate utilization is arrived at by comparison to neighbouring mature forest. In general, when a location has a poorly developed lichen crop, selective cutting only reduces that crop to a further low level. This was the case in the Avola Mountain 5 year old selective cut where low lichen abundance levels in the mature forest were not improved upon by cutting. Conversely, Graffunder Lake selectively cut stands had significantly higher lichen cover and abundance in

comparison to the mature forest adjacent to the cut blocks. Sporadic removal of large spruce (35 cm DBH) may have improved light conditions without removing lichen beyond some 'threshold level' where recovery of lichen standing crop is restricted. This 'threshold level' is difficult to predict because it depends on stand development. The best alternative for retention of lichen standing crop is to leave a number of heavily lichen covered, mid canopy, medium vigor Abies lasiocarpa. The actual number per hectare cannot be determined from this study. Tree DBH accounted for the greatest degree of variation in both lichen cover and abundance. There were a variable number of high DBH trees present on all the selectively cut sites. These trees were probably above the 12-14 inch limit at the time of logging but were not removed, either by ommission or the desire to protect residuals. These trees may have contributed to greater overall lichen abundance in the selective cuts. Although blow-down of large mid canopy subalpine fir may prove to be a problem, the trees may survive long enough to 'seed' the cutblock and they will be certain to add substantial lichen dispersal fragments to the residual stand.

There were several types of selective cut logging examined in this study. This was necessary in order to obtain an adequate range in ages. The range in age was probably not wide enough to record a clearly defined difference in lichen abundance or cover according to age. The history of logging in the Clearwater area documents a variety of logging techniques. Intermediate utilization (I.U.) seems to be the best method of logging for retention of lichen standing crop, but this method is probably not going to be repeated. The success of I.U. logging may be an artifact of a unique lichen standing crop at Graffunder Lake. The question why this location bears a good lichen crop should be addressed. Selective logging may cause interference with lichen patchiness. It may reduce total lichen cover and abundance in poorly covered residual stands. If stands are managed for retention of exceptional lichen bearing trees then some stand improvement may result.

Therefore, where diameter limit logging is to be used in a stand similar to the ones documented here, faller selection or marking of 'lichen seed

trees' is recommended. They should be fairly robust trees with evident lichen abundance. Further studies should determine the number of these trees required to maintain adequate lichen abundance for woodland caribou and whether caribou will use these stands.

5.4 Research Recommendations

A review of the methods for lichen abundance assessment is needed in light of the variety of methods for lichen inventory in British Columbia (Edwards et al. 1960, Schroeder 1972, Stevenson 1979, Antifeau 1981) in the rest of Canada (Raup 1930, Jesberger and Sheard 1972,) and in other countries (Forman 1975, Becker et al. 1977, Pike et al. 1977, Esseen et al 1981, Rhoades 1981). A refinement of a lichen abundance assessment technique that is accompanied by random lichen biomass sampling is recommended. To date the most accurate method for lichen abundance assessment is the 3P method adapted by Stevenson (1979).

From this study it is evident that percent cover estimates have a limited application. Perhaps they are of use in comparing ecological conditions between many selective cuts of similar age. Percent cover estimates may be the best method for sampling logging as recent as 3-7 years old. When studying different ages of selective cuts, percent cover estimates become secondary in importance to abundance estimates as older selective cuts are sampled. Although biomass verification is time consuming it is necessary in order to make predictions for unsampled stands. In older selective cuts the increase in percent cover may be minimal in comparison to the increase in abundance.

Plotless random sampling on transects may be useful as a mapping technique for reconnaissance. Lichen abundance distribution curves can be determined and areas of high, medium and low lichen abundance can be located for more intensive random sampling. Stands can be mapped and sampled accordingly. This may enable predictions for lichen abundance in whole stands and may help to normalize the data. The persistence of skewness and outliers may require exploratory data analysis techniques (Velleman and Hoaglin 1981).

The number of lichen poor trees was found to outnumber the number of lichen rich trees for any given plot or subplot. This is probably true for most Engelmann Spruce - Subalpine Fir stands with the exception of those patches of many high lichen bearing trees in Graffunder Lake and Jones Creek. Patchy distribution on high lichen abundance in other stands has been observed on Vancouver Island (Stevenson, pers. comm. 1982), Mnt. Baker (Rhoades, pers. comm.), the Ho River Valley and in the rainforests of Costa Rica (Nadkarni, pers. comm.).

Areas with lichen rich trees in Graffunder were approximately 4-5 hectares and grading into lichen poor stands. Optimal conditions for lichen biomass production have not been adequately explained. The lichen-poor areas at Graffunder were probably due to inadequate light conditions in dense forest stands. If high lichen abundance is the general rule for most trees within a fairly large area, then microenvironmental differences in light and moisture regimes are probably not as important as whole stand dynamics and major topographical differences. Comparisons of good lichen stands to poor lichen stands is recommended. Stand history, cold air drainage patterns, snow, fog and wind patterns over the long term may, in part, be used to explain developments of superior lichen crops. Whole stand assessment is possible but requires some careful elaboration of current forest inventory methods. Forest mensuration data alone probably does not give adequate information for lichen productivity analysis.

A comparative analysis of lichen abundance on spruce and balsam trees may be valuable. The type of forest stand information that is probably important and requires further research are: edge effect and its influence on light regime, tree and whole stand vigor, stand age and growth rate, stand fire history, and stand configuration. Tree vigor and lichen abundance can be investigated through a number of simple wounding experiments. A number of similarly covered trees should be observed over a time span of 10 to 15 years. Longevity and slow growth of individual lichen thalli makes this necessary. It appears there is a relationship between open or edge grown trees and lichen abundance. A large number of trees should be sampled in edge

and enclosed environments and compared. Again, long-term experiments are required owing to the slow growing nature of these plants.

The need for studies of Bryoria spp. and related species is evident. Lichen productivity studies will require some attention to be paid to Bryoriad lichen autecology. Microsite factors such as light availability at the branch level and how that changes with tree and stand growth, bark moisture potential, biochemistry and structure also need consideration with respect to lichen productivity.

6 CONCLUSIONS

This is a pilot study and it does not reveal growth rates of lichens as affected by age or type of selective cut. Older selective cuts may tend to have more abundant lichen than younger selective cuts but considerable between-plot variance makes age based comparisons tentative. The determination of Bryoria spp. growth rates and the conditions that might ameliorate those growth rates would be useful for insuring lichen recovery after logging. An inventory of standing crop prior to and at intervals after selective cutting would give a more accurate estimate of Bryoriad productivity.

This study suggests that the best type of tree for generally good lichen abundance is a mid-canopy, mid-life, medium vigor, open growing *Abies lasiocarpa*. Due to the clumped distribution patterns of lichen rich trees it is probably not possible to predict good lichen cover for a given stand on the basis of a high frequency of this type of tree alone, however. The safest method for insuring adequate lichen abundance is to leave many lichen-rich, medium vigor balsam greater than 28 cm DBH.

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APPENDIX 1A. Vascular plant species - releve table

Releve Number	5 Year old Cutblock			10 Year old Cutblock			15 Year old Cutblock			20 Year old Cutblock			Mature Forest Plots								
	18	15	14	3	5	7	9	12	10	20	17	1	7	4	19	16	6	8	11	13	
Abies lasiocarpa (Hook.) Nutt.	30	10	28	24	4	21	68	42	24	23	40	29	43	32	75	18	94	11	27	38	20
Menziesia ferruginea Smith	1	7	35	25	7	34	25	40	25	32	9	35	12	33	1	18	1	20	14	35	20
Picea engelmanni Parry	9	8	13	2	8	9	1	17	15	17	7	8	2	13	7	14	22	28	27	22	20
Gymnocarpium dryopteris (L.) Newm.	13	12	10	4	8	2	11	10	10	9	10	7	10	4	20	8	11	3	8	10	20
Vaccinium membranaceum Dougl.	5	1	2	11	7	2	20	5	2	12	18	25	5	10	5	2	2	1	4	6	20
Tiarella unifoliata L.	5	3	1	1	3	2	2	1	5	3	4	1	1	3	4	2	3	1	2	2	20
Rubus pedatus J.E. Smith	1	2	2	3	1	2	32	1	4	5	3	1	1	1	5	4	2	4	3	3	20
Vaccinium ovalifolium Smith	4	2	3	2	2	2	2	2	1	7	2	5	2	3	4	4	4	1	1	2	20
Streptopus roseus Michx.	3	3	3	6	3	3	4	2	4	7	4	4	6		5	3	4	1	3	4	19
Ribes lacustre (Pers.) Poir.	18	2	2	2	3	3		3	5	5	8	2	1	4	3	1	7		3	3	18
Valeriana sitchensis Bong	10	20	8	8	5	3		7	12	3	11	6	4	10	17	7	7		4	10	18
Lycopodium annotinum L.		1	2	3	1	3	1	1		1		1	1	1	2		2	3	1	2	16
Rhododendron albiflorum Hook.		9	5	20		30	10		7			17	8	15	25	14	10	60	8	40	15
Veratrum viride Ait.	5	2		1	1		1	1	3	1		1	1	3	8	1	1			1	15
Cornus canadensis L.			4			2	10	2		3	5	8	2			6	1	3	2	5	13
Clintonia uniflora (Schult.) Kunth.		2		2			4	1		1	2	2	1	1		2		1	2	1	13
Epilobium angustifolium L.	5	1	1	2	1	1		1	2		2	1			2		1				12
Dryopteris assimilis	1	3	2	1		1			1	1			1	1		1			1	1	12
Listera chordata (L.) R. Br.	1			1		1		1						1	1	1	1	1		1	10
Viola orbiculata Geyer.	1	1					1			1	1	1	1	1		1	1				10
Sorbus sitchensis Roemer	1	1		1			1		1			6	1	2				1			9
Athyrium felix-femina (L.) Roth.	3	1			1			1		1	2				7	1	1				7
Arnica latifolia Bong.	6	2													1	1	1				7
Orthelia secunda L.			1			1	1			1	1	1							1		7
Lonicera involucrata (Rich.) Banks	3									2		1	1		1		1				6
Paxistima myrsinites (Pursh.) Raf.							7			2		9	3	1							5
Hieracium albiflorum Hook.				1			1		1		2	1									5
Sambucus racemosa L.	1	1		1					2		1										5
Equisetum arvense L.				2	1				1						1		2				5
Oplopanax horridum (Smith) Miq.										1	3	1	2								4
Luzula parviflora (Ehrch.) Desv.	1			1					1						1						4
Mitella breweri Gray	1													1	1						4
Rubus idaeus L.		1								1	1										4
Bromus vulgaris (Hook.) Shear	4									1	1										4
Thalictrum occidentale Gray	18									1	1										3
Tsuga heterophylla (Raf.) Sarg.		1						3			1			1	1						3
Lupinus arcticus (Piper & Robins.) Smith	1											3			1						3
Goodyera oblongifolia Raf.							1				1							1			3
Streptopus amplexifolius (L.) DC.		1								1									1		3
Smilacina racemosa (L.) Desf.	1												1				1				3
Smilacina stellata (L.) Desf.										1	1	1			1						3
Viola glabella Nutt.	2	1													1						3
Alnus viridis (Regel) Rydb.											5										3
Spiraea betulifolia Pall.										1	1										1
Rubus parviflorus Nutt.										1					1						2
Chimaphila umbellata (L.) Bart.													1								2
Senecio triangularis Hook.	1			1																	1
Equisetum sylvaticum L.					2																2
Vaccinium caespitosum Michx.							1														1
Salix sp.					1						1								1		2
Rosa sp.					1																2
Acer glabrum Torr.		1						1													1
Carex sp.										1											2
Poa pratensis L.	2									2											1
Calamagrostis canadensis (Michx.) Beauv.	2									1											2
Bromus cerinatus H. & A.	2																				2
Pedicularis bracteosa Benth.	2																				1
Actaea rubra (Ait.) Willd.	17																				1
Heracleum sphondylium Michx.	6														2						2
Galium boreale L.	2														1						2
Arnica cordifolia Hook.	1																				1
TOTAL	38	24	29	24	19	18	21	19	22	28	31	26	24	21	29	20	23	15	19	18	

APPENDIX 1B: Common lichens, mosses and liverworts

Clearwater - Blue River ESSF 1980-81

Lichens	Mosses & Liverworts
Alectoria sarmentosa	Brachythecium sp.
Bryoria capillaris	Cephalozia sp.
Bryoria friabilis	Dicranum pallidisetum
Bryoria freemontii	Dicranum tauricum
Bryona fuscescens	Dicranum sp.
Bryoria lanestris	Hypnum circinale
Bryoria oregana	Lophosia lycopodiodes
Bryoria glabra	Lophosia sp.
Bryoria pseudofuscescens	Mnium nudum
Bryoria vrangiana	Mnium glabrescens
Bryoria sp.	Pleurozium schreberi
Bryoria sp.	Polytricum commune
Cetraria ciliaris	Ptilium crista - castrensis
Cladonia chloropheae	Rhytidiopsis robusta
Cladonia amaurocraea	Rhytidium rugosum
Cladonia bacillaris	Sphagnum sp.
Cladonia multiformis	
Cladonia coniocraea	
Cladonia cornuta	
Cladonia deformis	
Cladonia ecmocyna	
Cetraria canadensis	
Hypogymnia enteromorpha	
Hypogymnia bitteri	
Hypogymnia tubulosa	
Hypogymnia physodes	
Ichmadophila ericetorum	
Letharia vulpina	
Lobaria oregana	
Lobaria pulmonaria	
Nephroma parile	
Nephroma bellum	
Parmelia saxatilis	
Parmelia sulcata	
Parmeliopsis ambigua	
Peltigeria canina	
Peltigeria rufescens	
Peltigera polydactyla	
Peltigera venosa	
Platismatia glauca	
Stereocaulon tomentosum	

Appendix 2A. Selectively cut stands and mature forests: their elevation, logging history, timber type ans aspect: slopes range from 0-17%

Age	Selectively cut stand			Mature Forests		
	HARBOUR LAKES	AVOLA MNT.	RAFT MNT.	HARBOUR LAKES	AVOLA MNT.	RAFT MNT.
5	Elev. 1550 m winter logged 12" SB 210 M Aspect 325° Yrs since cut	Elev. 1460 m D.L. 14" SB 210 M Aspect 135°	Elev. 1560 m D.L. 14" BS 110 M Aspect 125°	Elev. 1555 m SB 941 M Aspect 320°	Elev. 1480 m SB 941 M Aspect 220°	Elev. 1530 m S (B) 941 M Aspect 118°
	AVERY LAKE	CANDLE CR.	JONES CR.	AVERY LAKE	CANDLE CR.	JONES CR.
10	Elev. 1535 m D.L. 12" S 110 M Aspect 48° Yrs since cut	Elev. 1530 m D.L. 14" SB 110 M Aspect 225°	Elev. 1625 m Salvage logged BS 93 Resid m Aspect 0°	Elev. 1520 m B(S) 831 P Aspect 225°	Elev. 1550 m SB 931 M Aspect 252°	Elev. 1600 m SB 841 M Aspect 325°
	GRAFFUNDER LAKE	OTTER CR.	HARBOUR LAKE	GRAFFUNDER LAKE	OTTER CR.	HARBOUR LAKE
15	Elev. 1370 m I.U. for spruce BS 52 Resid P Aspect 0°	Elev. 1600 m D.L. 14" BS 52 Resid M Aspect 275°	Elev. 1488 m D.L. 12" SB 210 P Aspect 0°	Elev. 1390 m BS 941 M Aspect 40°	Elev. 1535 m SB 941 M Aspect 260°	Elev. 1555 m SB 941 M Aspect 320°
	GRAFFUNDER LAKE	CANDLE CR.	GRAFFUNDER LAKE	GRAFFUNDER LAKE	CANDLE CR.	GRAFFUNDER LAKE
15	Elev. 1380 m I.U. for spruce BS 82 Resid poor & SB vets Aspect 43°	Elev. 1490 m High lead BS 83 Resid poor Aspect 248°	Elev. 1330 m I.U. for spruce BS 82 Resid poor & SB vest Aspect 40°	Elev. 1390 m BS 941 M Aspect 40°	Elev. 1550 m SB 931 M Aspect 252°	Elev. 1390 m BS 941 M Aspect 40°

Appendix 2B. Criteria for site selection

Category	Criteria	Description
Silvicultural history	No sanitation spacing	Sanitation spacing in one 5 year old site in same year as logging (Harbour Lakes)
Logging history	Preferably 12" diameter limit	5 year - Diameter limit 12" and 14" (Avola & Raft) 3 - 5 years elapsed since selectively cut. 10 year - Diameter limit of 12" and 14" and salvage logging 10" DBH (Jones Crk.) 8-12 years elapsed since selectively cut 15 year - Diameter limit of 12" and 14" and intermediate utilization for large spruce and balsam (Graffunder Lk.) 15-18 years elapsed since selectively cut 20 year - Intermediate utilization for large spruce (Graffunder Lk.) and high lead logging on Candle 20 year site. Greater than 20 years elapsed since selectively cut
Elevation	1400 - 1600 m	5 year = 1523 m S.D. 55 m 10 year = 1561 m S.D. 50 m 15 year = 1486 m S.D. 115 m 20 year = 1400 m S.D. 82 m
Aspect	Plots should not vary more than 90° from the most common aspect	5 year = N and SW 10 year = N and E 15 year = N and E 20 year = N and E
Slope	0-30%	5 year = 11.6% S.D. 3.5 10 year = 11.6% S.D. 6.6 15 year = 5.3% S.D. 9.2 20 year = 11.0% S.D. 0.1
Site position	Midslope	Lower slope to upper slope
Ecological moisture	Mesic	Mesic to subhygric

APPENDIX 3A. Histograms of lichen cover per plot

	Lichen Estimate	Number of Observations	
RAFT	0	20	**********
	5	12	**********
	10	11	**********
	15	0	
	20	2	**
	25	2	**
	30	1	*
	35	0	
	40	1	*
	45	0	
	50	0	
	55	0	
	60	1	*
AVOLA	0	1	*
	1	26	**********
	2	6	******
	3	0	
	4	7	*******
	5	1	*
	6	2	**
	7	0	
	8	7	*******
	9	0	
	10	5	*****
HARBOUR	0	17	**********
	5	10	**********
	10	13	**********
	15	1	*
	20	0	
	25	1	*
	30	2	**
	35	0	
	40	0	
	45	0	
	50	0	
	55	0	
	60	2	**

	Lichen Estimate	Number of Observations	
JONES	0	16	**********
	5	8	********
	10	10	**********
	15	1	*
	20	2	**
	25	1	*
	30	3	***
	35	0	
	40	1	*
	45	1	*
	50	1	*
	55	1	*
AVERY	0	0	
	2	16	**********
	4	15	**********
	6	1	*
	8	2	**
	10	5	*****
	12	3	***
	14	2	**
	16	3	***
	18	0	
	20	1	*
	22	1	*
	24	0	
	26	1	*
CANDLE	0	13	**********
	5	13	**********
	10	15	**********
	15	0	
	20	8	********
	25	3	***
	30	0	
	35	0	
	40	0	
	45	0	
	50	2	**

	Lichen Estimate	Number of Observations	
OTTER	0	22	**********
	10	16	**********
	20	2	**
	30	4	****
	40	1	*
	50	1	*
	60	1	*
	70	0	
	80	1	*
	90	0	
	100	0	
	110	0	
	120	1	*
HARBOUR	0	19	**********
	10	23	**********
	20	2	**
	30	3	***
	40	0	
	50	0	
	60	0	
	70	0	
	80	1	*
GRAFFUNDER	0	7	*******
	10	10	**********
	20	7	*******
	30	6	******
	40	6	******
	50	6	******
	60	1	*
	70	4	****
	80	2	**

	Lichen Estimate	Number Observations	
CANDLE	0	24	**********
	10	22	**********
	20	1	*
	30	0	
	40	2	**
	50	0	
	60	0	
	70	0	
	80	0	
	90	1	*
GRAFFUNDER	0	9	*********
	5	3	***
	10	9	*********
	15	2	**
	20	2	**
	25	3	***
	30	7	*******
	35	2	**
	40	4	****
	45	2	**
	50	1	*
	55	0	
	60	4	****
	65	1	*
GRAFFUNDER	0	18	**********
	10	13	**********
	20	5	*****
	30	4	****
	40	3	***
	50	3	***
	60	3	***
	70	1	*

	Lichen Estimate	Number of Observation	
AVOLA MATURE	0	23	**********
	4	14	**********
	8	5	*****
	12	4	****
	16	1	*
	20	1	*
	24	1	*
	28	0	
	32	1	*
RAFT MATURE	0	26	**********
	5	10	**********
	10	7	*******
	15	3	***
	20	2	**
	25	0	
	30	1	*
	35	0	
	40	0	
	45	0	
	50	1	*
AVERY MATURE	0	25	**********
	4	7	*******
	8	8	********
	12	4	****
	16	1	*
	20	4	****
	24	0	
	28	1	*
CANDLE MATURE	0	29	**********
	2	9	*********
	4	2	**
	6	2	**
	8	2	**
	10	2	**
	12	1	*
	14	1	*
	16	0	
	18	1	*
	20	1	*

	Lichen Estimate	Number of Observations	
GRAFFUNDER	0	19	**********
MATURE	4	17	**********
	8	7	*******
	12	2	**
	16	0	
	20	0	
	14	2	**
	18	1	*
	32	2	**

Appendix 3B. Histograms of lichen abundance per plot

5 Year old Sites

	Lichen Estimate	Number of Observations	
AVOLA MNT.	0	14	**********
	1	12	**********
	2	8	********
	3	4	****
	4	2	**
	5	1	*
	6	1	*
	7	3	***
	8	0	
	9	1	*
	10	1	*
RAFT MNT.	0	35	**********
	10	12	**********
	20	0	
	30	2	**
	40	0	
	50	0	
	60	0	
	70	0	
	80	1	*

10 Year old Sites

	Lichen Estimate	Number of Observations	
CANDLE CRK.	0	23	**********
	5	18	**********
	10	2	**
	15	4	****
	20	0	
	25	1	*
	30	0	
	35	0	
	40	1	*
	45	1	*

15 Year old
Sites

	Lichen Estimate	Number of Observations	
GRAFFUNDER	0	8	********
	2	12	**********
	4	13	**********
	6	7	*******
	8	3	***
	10	2	**
	12	0	
	14	1	*
	16	1	*
	18	1	*
	20	1	*
	22	1	*
OTTER	0	21	**********
	5	15	**********
	10	2	**
	15	3	***
	20	1	*
	25	1	*
	30	2	**
	35	2	**
	40	0	
	45	0	
	50	2	**

20 Year old
Sites

	Lichen Estimate	Number of Observations	
GRAFFUNDER	0	8	********
	4	8	********
	8	9	*********
	12	10	**********
	16	4	****
	20	5	*****
	24	1	*
	28	0	
	32	3	***
CANDLE	0	20	**********
	2	11	**********
	4	7	*******
	6	4	****
	8	2	**
	10	1	*
	12	0	
	14	1	*
	16	1	*
	18	1	*
	20	0	
	22	0	
	24	1	*
	26	1	*
GRAFFUNDER	0	14	**********
	5	9	*********
	10	8	********
	15	4	****
	20	3	***
	25	2	**
	30	5	*****
	35	1	*
	40	0	
	45	0	
	50	3	***
	55	1	*

APPENDIX 3C. F-MAX Tests for heterogeneity

				Test	P
ABUNDANCE	$\frac{\text{Max variance}}{\text{Min. variance}}$	$\frac{.338}{.1444}$	= 2.34	(F-max 2.34)	.001 n.s.
COVER	$\frac{\text{Max. variance}}{\text{Min. variance}}$	$\frac{.423}{.1443}$	= 2.96	(F-max 2.96)	.001 n.s.

APPENDIX 3D. 4-Way Analysis of Variance, class level information: variable amalgamations

Class Levels	Values	Amalgation
Tree vigor	1) Dead 2) Poor 3) Medium 4) Good 5) Super	1) Poor and medium 2) Good and super
Tree distribution	1) Open 2) Closed on one side of the crown 3) Closed on two sides 4) Closed on three sides 5) Closed on four sides 6) Clumped 7) Super clumped	1) Open and closed on one side 2) Closed on two and three sides 3) Closed on four sides, clumped and super clumped
Stand density		1) 20 trees per plot 2) 20 trees per plot
Stand age	5 years since cut 10 years since cut 15 years since cut 20 years since cut Mature forests	5 10 15 20 25

Note: Number of observations in data set = 765 (trees)

APPENDIX 3E. Skewness, variance and kurtosis

VARIABLE:LICHEN COVER

MOMENTS

N	1147	Variance	154.481
Mean	10.1292	Kurtosis	3.42172
STD Dev.	12.429	Skewness	1.917
T:Mean	27.6006	STD Mean	0.366991
D:Normal	0.229577		

VARIABLE: LICHEN ABUNDANCE

MOMENTS

N	798	Variance	83.9112
Mean	5.90363	Kurtosis	11.3027
STD Dev.	9.16031	Skewness	2.92047
T:Mean - 0	18.2058	STD Mean	0.324271
D:Normal	0.259632		

APPENDIX 4. Forest cover map plot locations and field data forms

LOCATION	FOREST COVER MAP
Candle Creek	82 - M - 12c
Graffunder Lake	82 - M - 12a
Otter Creek	82 - M - 11f
Raft Mountain	82 - M - 12e
Harbour Lakes	82 - M - 11b
Avery Lake	82 - M - 12b
Avola Mountain	82 - M - 14e
Jones Creek	82 - M - 12c

FIELD DATA FORM

LOCATION	MAT/CB	PLOT NO.	SUBPLOT #					DATE: AGE: LOCATION:																	
								0-2 m					2-4 m					4-6 m							
TREE NO.	SPECIES	VIGOR	DBH	HT.	CROWN W.	% LIVE CR.	RELEASE	DISTRIB.	LICHEN W.		% LIVE	% LICHEN	VOLUME	SPECIES	% LIVE	% LICHEN	VOLUME	SPECIES	% LIVE	% LICHEN	VOLUME	SPECIES	AGE	CLUMP	WIDTH CW.	NOTES

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